Thermomechanical analysis of cyclic deformation of glass materials: methodology and first results

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Abstract. A cyclic bending test is carried out with soda lime glass specimens. Temperature variations are measured at the specimen surface by using high resolution infrared camera. These thermal measurements are used for thermoelastic stress analysis and heat power density calculation. Full stress and heat power density fields are mapped at the specimen surface. The evolution of temperature variation is finally studied to characterize the effects of mechanical cycles and loading conditions on the thermal response.

Introduction

Thermal and calorific effects accompanying the deformation of materials are widely studied in literature to investigate thermomechanical couplings, fatigue, failure and plastic instabilities, non-exhaustively. Most of applications deal with metals, but polymers, ceramics and composite materials are also studied. Concerning inorganic glass materials, studies generally focus on crack tip movement and mechanical properties [1] or fracture [2,3,4]. To the best knowledge of the authors, the thermal response has never been considered to investigate the mechanical behavior of inorganic glasses. The first objective of the present work is therefore to evidence thermal and calorimetric effects in a soda lime glass subjected to cyclic loadings at room temperature. For this purpose, infrared (IR) thermography is used to measure the full temperature field and Thermoelastic Stress Analysis (TSA, see [5,6]) technique is used to provide the corresponding stress* map at the surface of glass specimens. Moreover, full heat power density field is deduced from the temperature measurements by using the heat diffusion equation. The second objective of this study is to investigate the effects of mechanical cycles on the thermal response of glass.

Experimental setup

The glass considered in the present study is a soda lime glass. The specimen is 20 mm in length, 5 mm in width and 3 mm in thickness. It was tested under cyclic bending loading by means of a 5543 instron testing machine. An overview of the experimental setup is given in Figure 1. The shape of the effort signal was triangular. The full thermal field was measured at the specimen surface during the cyclic tests.

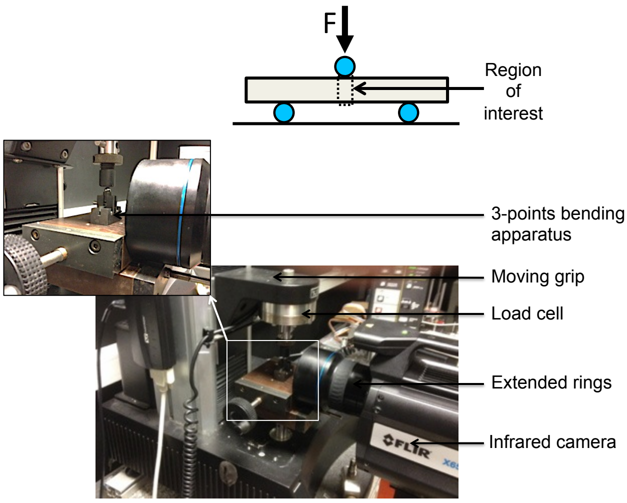

Figure 1: Overview of the experimental setup (at the bottom) and schematic view of the 3-points bending test (at the top)

Results and discussion

Figure 2 presents maps of the temperature variation range (the peak-to-peak amplitude) at the observed surface, which enables us to evaluate the level of the temperature variation amplitude according to the cyclic loading applied. Besides, such maps enables us to identify the zones of highest thermal activity for a given cyclic loading condition.

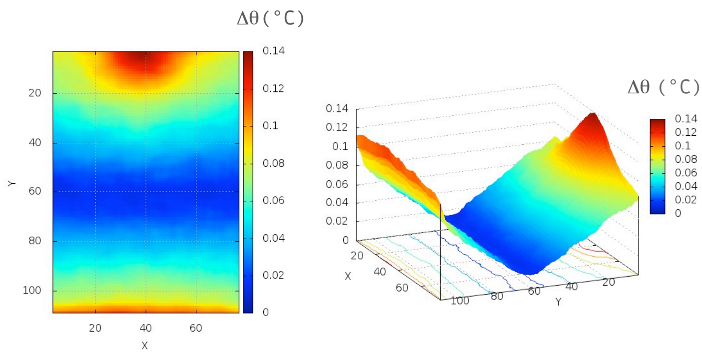

Figure 2: Temperature variation range obtained

The results obtained show that the order of magnitude of the temperature variation range is a tenth of a degree for the highest loading conditions applied, which corroborates the previous results obtained in ref. [7]. Then, the full stress field is deduced from the temperature field by assuming that the test is performed under quasi-adiabatic condition. Results show that under the maximum loading conditions applied, the higher stress value can reach more than 100 Mpa in the Hertz point zone [8]. Finally, heat power density field (maximum over the cycle) has been calculated from temperature variation field by using the heat diffusion equation. The maps of heat power density are used to figure out the effects of cyclic deformation on the thermomechanical response of glass.

Conclusion

This study has investigated the thermomechanical behavior of sodalime glass. The framework of the TSA has been used to map the stress field at the surface of the specimen. A classical thermoelastic response is observed. Moreover, thermal measurements have been processed to calculate heat sources absorbed and produced by the material according to the considered change in the mechanical state. Finally, original results dealing with the evolution of temperature variations during mechanical cycles have been obtained.

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** here, the term stress means the sum of principal stresses*